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D. Currently Applicable Classification Level: Unclassified

This work was supported by _ARPA___________ under Contract Number N00600-92-C-3377____________.

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Network Architecture and SONET Services in the NASA-ARPA Gigabit Satellite Network using NASA's Advanced Communications Technology Satellite (ACTS)

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***Abstract* — The Gigabit Satellite Network, a project jointly sponsored by ARPA and NASA, will provide long-haul STS-3 (155.54 Mb/s) and STS-12 (622.08 Mb/s) point-to-point and point-to-multipoint full-duplex services over NASA's Advanced Communications Technology Satellite (ACTS). Data multiplexing over the satellite will be accomplished using TDMA techniques coordinated with the switching and beam hopping facilities provided on-board the ACTS. Transmissions to the satellite will be protected using Reed-Solomon encoding, providing almost error-free clear-sky transmissions and, in the case of rain-fade, bit error rates better than 10^{-11} 99.0% of the time. Unique to the system architecture are a TDMA frame structure and satellite synchronization mechanisms that, together, will allow (1) very efficient utilization of the satellite capacity, (2) over-the-satellite closed-loop synchronization of network configurations with up to 64 earth stations, and (3) earth station initial acquisition without collisions with existing signaling or data traffic. The end-user interfaces will use fiber-optics and will be compatible with SONET standards for fiber-based terrestrial networks. The terrestrial interfaces at the earth stations will perform the function of conventional SONET multiplexers and, as such, can be readily integrated with standard SONET fiber or radio-based terrestrial networks. As SONET multiplexers in the SONET hierarchy, the earth stations will synchronize the geographically-separated end-user interfaces. This synchronization will be implemented by terminating the section and line overheads of the SONET frames at the transmitting end of each satellite link, by transporting the payloads plus payload-pointer-bytes over the satellite, and by regenerating the SONET frames and corresponding section and line overheads at the receiving ends of the satellite links. Management of the network will be based upon the Internet Protocol (IP), including an over-the-satellite signaling network and backup terrestrial IP-based connectivity.**

I. Overview

The Gigabit Satellite Network project is jointly sponsored by ARPA and NASA[1] for the main objective of providing over-the-satellite long-haul concatenated and non-concatenated SONET STS-3 (155.54 Mb/s) and SONET STS-12 (622.08 Mb/s) point-to-point and point-to-multipoint services to system experimenters using the beam-hopping and on-board switching capabilities of NASA's Advanced Communications Technology Satellite (ACTS) [1]. The ground terminals for this system, the Gigabit Earth Stations (GESs), are mounted in trailers and will be deployed to the system experimenter premises to allow direct connection to end-user equipment. These GESs will be equipped with standard SONET OC-3/3c (155.54 Mb/s) and SONET OC-12/12c (622.08 Mb/s) fiber interfaces and will be capable of demultiplexing incoming non-concatenated STS-3 and STS-12 data streams into their STS-1 (51.84 Mb/s) components. These STS-1 signals will then, under network operator control, be routed independently to other GESs in the network [2, 3]. Direct support of fiber interfaces at OC-1 data rate (51.84 Mb/s) will be possible only through an external multiplexing equipment. The equipment for this system and associated network software is being developed by Bolt Beranek and Newman Inc. (BBN) with the IF and RF sections subcontracted to Motorola Government and Systems Technology Group.

The satellite network, from the end-user point of view, has been designed to replicate the functions of terrestrial SONET-based fiber networks. The Gigabit Earth Station performs the functions of a SONET Line Terminating Equipment (LTE) in the SONET hierarchy. The GES-to-GES communication over the satellite replicates the functions of an LTE-to-LTE communication in a terrestrial SONET network, where the section and line overheads of the SONET frames are terminated locally at the GESs and the SONET Synchronous Payload Envelope (SPE) bytes are transported and/or multiplexed over the satellite network. The GESs, while functioning as a SONET LTE, are capable of (1) performing frame alignment (justification) of incoming SONET frames to internally generated satellite frame signals, (2) multiplexing STS-1 and STS-3 signals into STS-3 and/or STS-12 signals, (3) terminating the section and line overheads of the SONET frames at the terrestrial interfaces, and (4) monitoring the operational status and the performance of the fiber links [4].

Transmissions to the satellite are performed at Ka-band (30/20 GHz) at 348 Mb/s and 696 Mb/s using BPSK and QPSK modulations respectively. The satellite links when operating at 696 Mb/s using QPSK modulation will have negligible bit error rate (BER < 10^{-12}) in clear-sky conditions and bit error rate performance comparable to a single SONET fiber loop (BER ≈ 10^{-11}) when in the presence of rain-fade. The encoding techniques (Reed-Solomon), the antenna diameter (3.4 meter), and the TWTA power levels (120 Watts) have been selected, along with other system components and parameters, to provide a rain-fade availability in excess of 99.0% for transmissions at 696 Mb/s and 10^{-11} bit error rate (BER).

[1] The work described in this paper is being funded by ARPA and NASA through NRCC contract number N00600-92-C-3377.

Data multiplexing over the satellite uses Time Division Multiple Access (TDMA) techniques adapted for operation with multiple antenna beams, on-board switching, and very fast beam hopping. Switching on-board the satellite is performed at the IF level (3 GHz) without signal demodulation/re-modulation (bent pipe). Transmissions from the GESs are performed in bursts with modulation type (BPSK or QPSK) and associated data rates (348 Mb/s or 696 Mb/s) being selectable on a per burst basis. BPSK transmissions at 348 Mb/s are reserved mainly for internal signaling and as a backup mechanism for achieving improved BER or greater rain-fade availability for end user data.

This paper is organized as follows. In Section II we provide a high-level view of the network architecture, including descriptions of the Earth Station equipment, Multibeam Communications Package (MCP) on-board the ACTS and ground coverage. Earth station synchronization with the ACTS on-board switching electronics and the mechanisms that allow sharing of the satellite capacity between multiple earth stations are central to the system and, in Section III, we provide summarized description of the Satellite-Switched Time Division Multiple Access (SS-TDMA) subsystem. In this section we also describe the approach used to create the internal over-the-satellite signaling infrastructure, and the support provided to bring up new earth stations into the network. Support of SONET services, even for terrestrial networks, is still in its infancy, with the interpretation and level-of-implementation of the various SONET standards varying from manufacturer to manufacturer. In Section IV we describe how the SONET frames are multiplexed and transported over the satellite and provide a characterization of the functionality that will be supported in the GES SONET interfaces by the time the network is deployed. Through the SONET interfaces, high-data-rate communication experimenters will be able to establish long-haul point-to-point and point-to-multipoint STS-3/12 links via satellite for experimentation with ATM protocols, distributed super computing, and remote access to full-motion video databases. Also in Section IV we illustrate a possible configuration of the satellite network to support HIPPI and ATM end-user applications over SONET interfaces.

II. Gigabit Satellite Network Architecture

The architecture of the Gigabit Satellite Network is illustrated in Figure 1. It is composed of transportable Gigabit Earth Stations

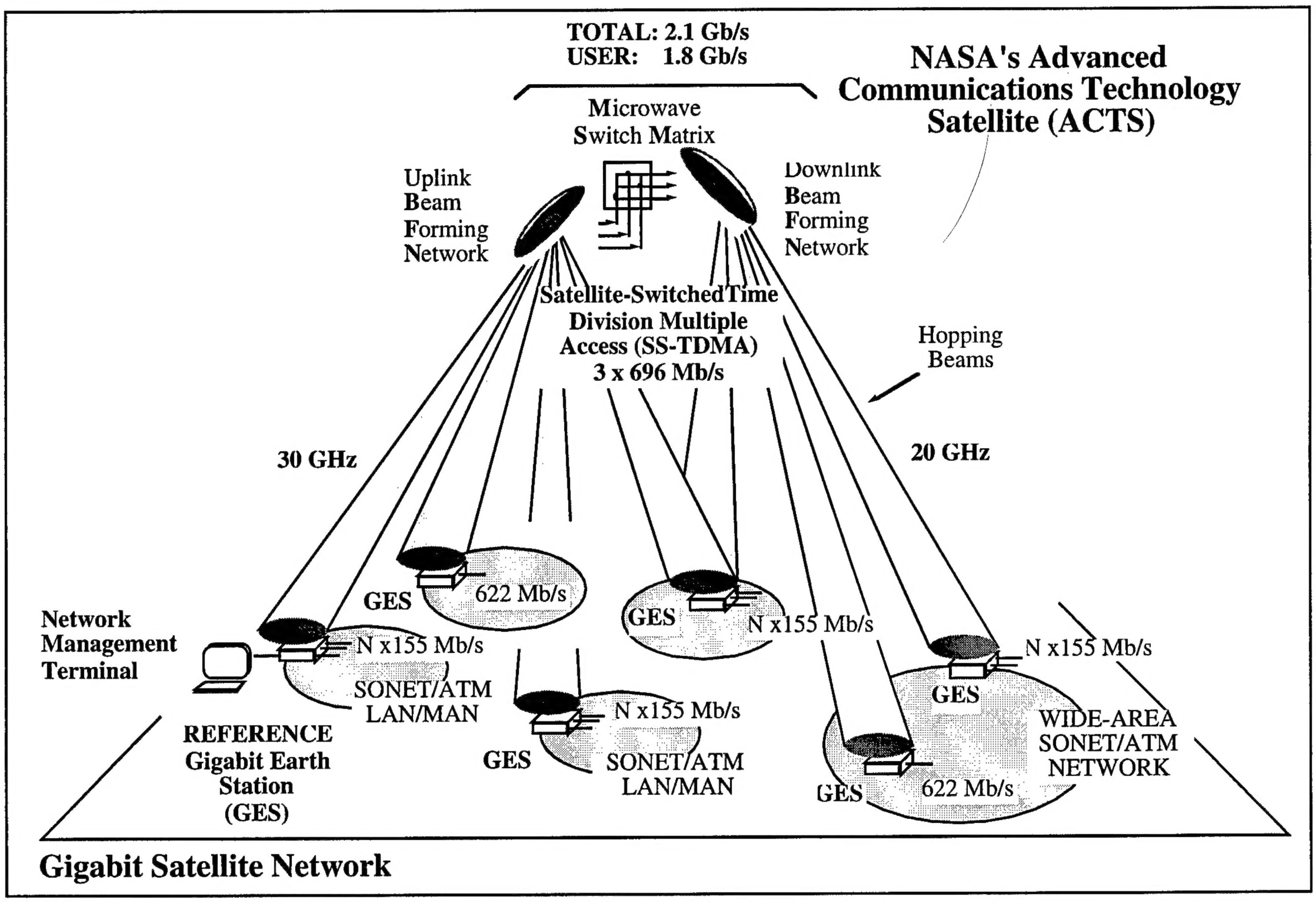

Fig. 1 - The Gigabit Satellite Network supports SONET interfaces at OC-3 and OC-12 speeds and provides network operators with direct over-the-satellite access to all Gigabit Earth Stations.

(GES), with fiber-optic SONET interfaces, which communicate directly over satellite using the antenna beams and the on-board uplink-to-downlink beam switching capabilities of ACTS. The network control and management functions are distributed in the various GESs with the operator's interface being centralized in a Network Management Terminal (NMT). The NMT can be located at any GES site or, alternatively, at any location with terrestrial Internet connectivity to a GES designated as reference station. The end user services of this network are configurable point-to-point or point-to-multipoint 155 Mb/s and 622 Mb/s SONET "links" over satellite. The network control and management functions make use of the standard SNMP protocol and are accessible from the Network Management Terminal. Authorized operators can also access certain network control and management functions from console interfaces local to the Gigabit Earth Stations or remotely through the Internet and dial-up modems.

Transmissions to the satellite are performed using Satellite-Switched Time Division Multiple Access (SS-TDMA) techniques with on-board space-time-space switching being performed by the High-Data-Rate section of the ACTS Multibeam Communications Package. Up to three uplink and three downlink antenna beams can be active simultaneously, that combined with 696 Mb/s burst rates per antenna beam, results in an aggregate system bit rate in excess of 2 Gb/s. Forward Error Correction (FEC) and overhead functions use approximately 10% of the total system bandwidth, resulting in end-user aggregate throughput in excess of 1.8 Gb/s (3 x OC-12).

A Earth Station Equipment

The components of the Gigabit Earth Station are illustrated in Figure 2. It includes a 3.4m antenna (from Prodelin), 30/20 GHz RF electronics, 3 GHz up/down converters, and a 696 Mb/s burst modem (from Motorola), and a Digital Terminal (from BBN). The Digital Terminal is capable of supporting fiber-optic SONET interfaces at 155.52 Mb/s (OC-3) and 622.08 Mb/s(OC-12). The Digital Terminal is also equipped with an Ethernet and local console interfaces.

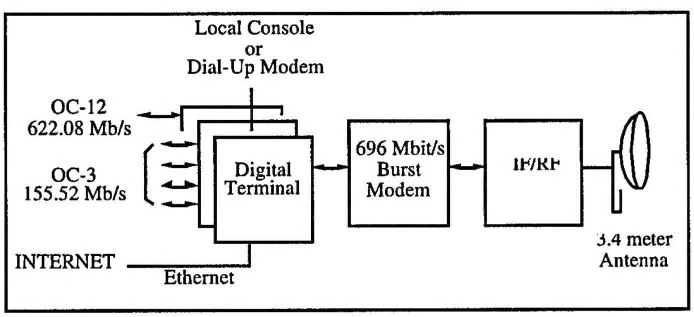

Fig. 2 - The Gigabit Earth Station is transportable, operates at Ka-band, and provides fiber-optic SONET interfaces for users at 155.52 Mb/s (OC-3/3c) and at 622.08 Mb/s (OC-12/12c).

The burst demodulator uses a patented phase rotator approach, is capable of performing both clock and carrier recovery with very short preambles (< 2 microseconds). The antenna diameter was selected as the maximum diameter possible for which satellite tracking is not required. The earth stations were designed for transportability and a trailer is used for moving the equipment from site to site. The trailer contains a weather-protected/ temperature-controlled cabin for the indoor electronics, and a sufficiently large area to transport the outdoor electronics and one disassembled antenna. The burst modem can operate with BPSK (348 Mb/s) or QPSK (696 Mb/s) modulations. All burst preambles, including the Unique Word (UW), and the internal signaling messages are transmitted using BPSK modulation. SONET data can be transmitted using either BPSK or QPSK modulation, selectable on a per burst basis. Table 1 provides a summary of key performance parameters.

Table 1
Key Performance Parameters

	Nominal E_b/N_0 (theory + 3 dB)	Channel Input BER	(232,216) Reed-Solomon Output BER	Pr{miss}
QPSK	10.9	2.4×10^{-4}	$< 10^{-11}$	-
BPSK	13.9	3.5×10^{-7}	$< 10^{-15}$	$<10^{-15}$

B. ACTS Multibeam Communications Package

The ACTS spacecraft includes a 2.2-meter 30 GHz receiving antenna and a 3.3-meter 20 GHz transmitting one, each with its own beam forming network, and a 1-meter 20/30 GHz mechanically steerable antenna. The on-board Multibeam Communications Package, shown in Figure 3, includes a 3x3 Microwave Switch Matrix (MSM) for high-bandwidth "bent-pipe" signals (the High-Data-Rate or HDR Section) and a Baseband Processor with signal demodulation/modulation, forward error correction (FEC) and digital switching capabilities (the Low Burst Rate or LBR Section). The multibeam antenna feedhorn network and the Ka-band transmitters and receivers are shared by the LBR and HDR sections.

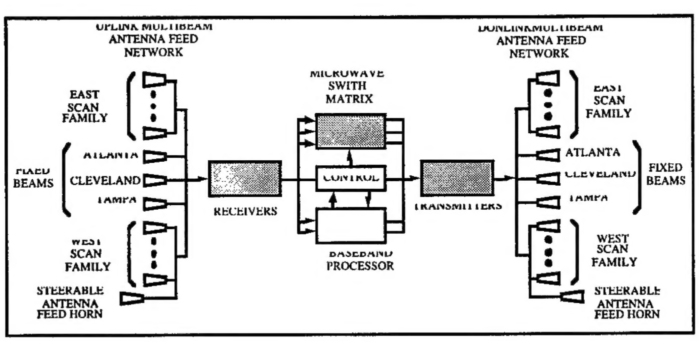

Fig. 3 - The ACTS on-board communication system can be set to operate in a High-Data-Rate (HDR) or Low Bit Rate (LBR) mode with Earth coverage provided by independent transmit and receive multibeam antenna feed networks.

For all cases of practical interest, the LBR and HDR sections (or modes) will not operate simultaneously. Selection of a particular mode of operation is performed through operator commands entered at NASA's Master Ground Station (MGS) and transmitted to the satellite via the TT&C channel. When in the HDR mode of operation , the baseband processing capabilities of the ACTS satellite are not used. The Gigabit Satellite Network (GSN) uses the HDR section of the ACTS satellite.

C. Antenna Beams and Ground Coverage

The multibeam antenna includes fixed beams to Cleveland, Atlanta and Tampa, the mechanically-steerable antenna beam, and two family of electronically steerable beams (also called hopping or scanning beams): the East Scan Beam and the West Scan Beam. The ACTS coverage, shown in Figure 4, is composed of isolated beam spots (6 East Scan beam spots and 7 West Scan beam spots) and two continuous sectors, East and West, composed respectively of 12 and 22 adjacent beam spots. The steerable antenna can be pointed to any point within the field of view of the satellite (Hawaii, Alaska, etc.) and, for burst scheduling purposes, can be viewed as an integral part of the West Scan Beam family.

D. Rain-Fade Margins

Ka-band transmissions can be severely affected by rain-fade. The satellite link parameters were selected for operation at very low BER in clear-sky weather and satellite link operation with performance that is comparable to fiber-optics (BER < 10^{-11}) during at least 99.0% of the time (rain-fade availability). Table 2 lists the EIRP and G/T at the center of the beam for a sample network sites[3]. Also shown are the corresponding uplink-and-downlink margins for 99.5% rain-fade availability [5].

Table 2
ACTS Link Parameters for a Sample Network

	EIRP dBW	G/T dB/°K	Rain Fade Margin for 99.5% Availability Uplink	Downlink
Cleveland, OH	68.0	22.4	7.0	3.0
Urbana, IL	63.6	18.9	7.0	3.0
Denver, CO	66.4	21.4	3.0	1.0
NASA AMES, CA	61.9	20.2	3.0	1.0
Boston, MA	63.9	19.5	8.0	4.0
Houston, TX	67.3	22.5	8.0	5.0

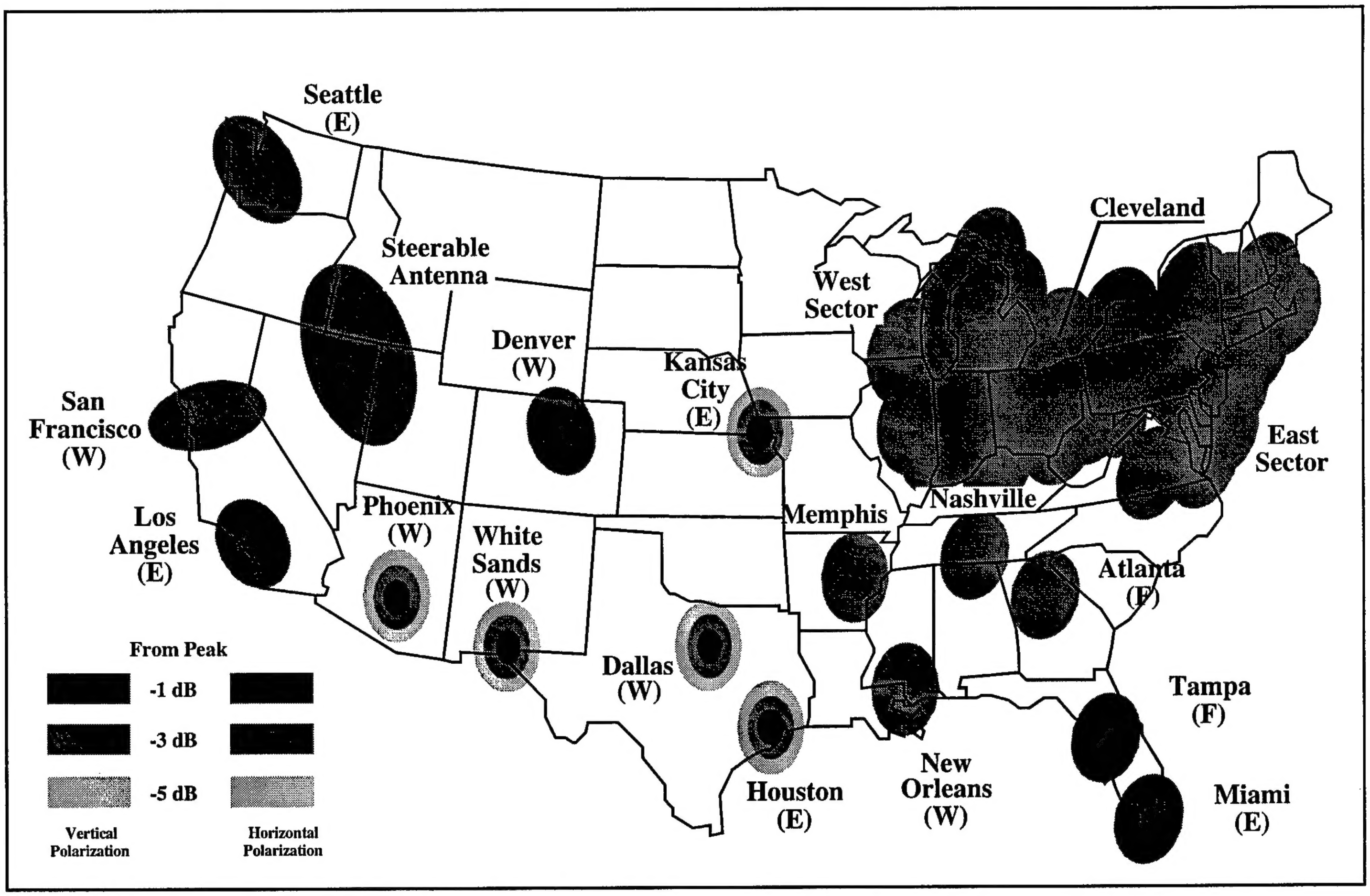

Fig. 4 - The ACTS multibeam coverage is formed by isolated beam spots and continuous East and West sectors.

Kansas City, KS	67.3	22.7	6.0	3.0

III. SS-TDMA Subsystem

A. Frame Architecture

The MSM control memory on-board the satellite has 1000 slots and can be configured to operate either with 1-ms or 32-ms frames. The Gigabit Satellite Network uses the latter with a 32-millisecond TDMA frame synchronized to the MSM frame, illustrated in Figure 5. The TDMA frame is subdivided into eight 4-ms TDMA sub frames, with each TDMA Subframe being further partitioned in signaling (Common Signaling and Synchronization Channel - CSSC) and data areas. Each 4-ms TDMA subframe corresponds (and is synchronized) to one-hundred-and-twenty-five 32-microsecond MSM slots, with 3 slots being used for synchronization and internal network signaling (CSSC - Common Signaling and Synchronization Channel), and 122 slots being available for end user data traffic (97.6% frame efficiency). This approach was selected because it allows distribution of the CSSC time slots along the whole 32-millisecond frame and is still well within the maximum switching rates specified for the MSM (please see references [1] and [6]).

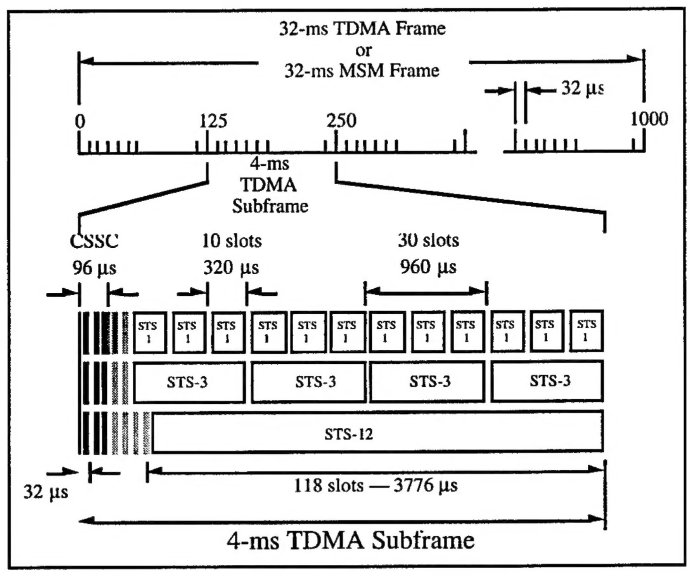

Fig. 5 - The TDMA Sub frame is synchronized with the MSM frame and its structure is oriented to handle SONET STS-1, STS-3, and STS-12 signals, with minimum overhead for internal signaling and synchronization to the satellite.

This approach also allows use of longer guard times (on the order of 2 microseconds, compatible with the MSM switching times on-board the satellite), and use of longer burst preambles (on the order of 6 microseconds) without impacting the overall frame efficiency. The data area (occupying a total of 120 slots per 4-millisecond frame) is used for STS-1 (51.84 Mb/s), STS-3 (155.52 Mb/s), or STS-12 (622.08 Mb/s) bursts. In the initial implementation, the incoming data on any OC-3 or OC-12 SONET interface, concatenated or not, will be broken into STS-1 bursts to reduce the amount of data lost in the case of missed bursts and to simplify the TDMA burst time plans. The

utilization of longer bursts (e.g., an STS-12 burst occupying 118 slots) will be reserved for potential asymmetrical services as in applications involving SONET OC-12 multicast in one direction and multiple lower speed IP channels at T1 or T1 sub-rate in the return path.

The worst-case frame efficiency occurs for the case of twelve STS-1 bursts, corresponding to a net end-user efficiency of 87.1% (ratio between number of end-user payload bytes divided by total number of channel bytes], assuming transmissions at 696 Mb/s using QPSK modulation.

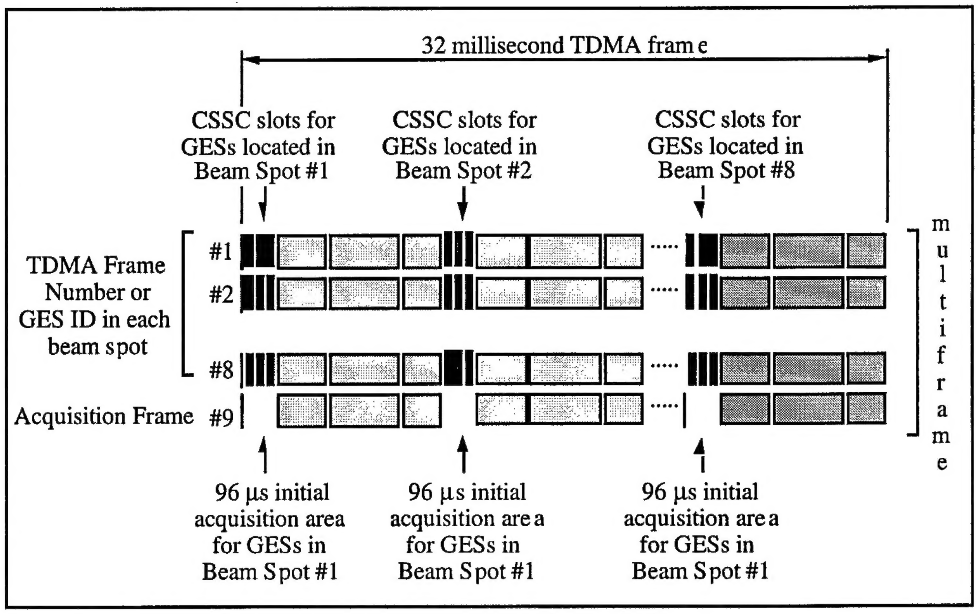

Fig. 7 - The multiframe structure allows multiple earth stations to share a single beam spot and creates an acquisition frame with large unused areas for new earth station initial transmissions to the satellite.

B. CSSC Subsystem and Synchronization

a) Star Signaling Architecture

All GESs in the Gigabit Satellite Network are identical. Any of the GESs can be configured (through operator commands from the NMT) to function as a Reference Terminal. The CSSC internal signaling subsystem has a star architecture with the Reference Terminal at the center of the star. The internal signaling infrastructure provides support for earth stations distributed in up to 8 different beam spots selected arbitrarily among Fixed, East Scan, West Scan, or steerable antenna spots (Figure 6).

The CSSC slots of successive TDMA Subframes are assigned cyclically to the different beams, in such a way that earth stations located in all participating beam spots have a chance, once per TDMA Frame, to transmit to and receive from the Reference Terminal (inbound and outbound signaling bursts, respectively). The remaining CSSC time slot is a ranging slot, used for direct loop-back synchronization. The Reference Terminal is also capable of relaying CSSC messages between Traffic Terminals.

b) Multiframe and Earth Station Initialization

The TDMA frame architecture includes a simple multiframe structure, shown in Figure 7, to allow multiple earth stations to share a single beam spot and, at the same time, to create a large enough frame area free of signaling and/or data bursts, reserved for initialization of new earth stations. The CSSC time-slots of earth stations physically located in one same beam spot are assigned to successive frames of the multiframe in a round-robin fashion. The multiframe length (= number of 32-ms frames) can be configured by the NMT operator and is always made larger than the maximum number of earth stations in any of the beam-spots. The CSSC slot areas (96 microseconds each) of the Acquisition Frame (last frame of the multiframe) are reserved for new (or restarting) earth stations to perform initial satellite acquisition. The 96-microsecond acquisition window is wide enough to allow these new earth stations to transmit to the satellite without colliding with adjacent traffic data bursts.

c) TDMA - MSM Frame Synchronization

The Reference Terminal and the Traffic Terminals each transmit a Synchronization Burst every multiframe with a dual objective: (1) to perform the round trip measurements required for direct-loopback TDMA frame synchronization, and (2) to track the

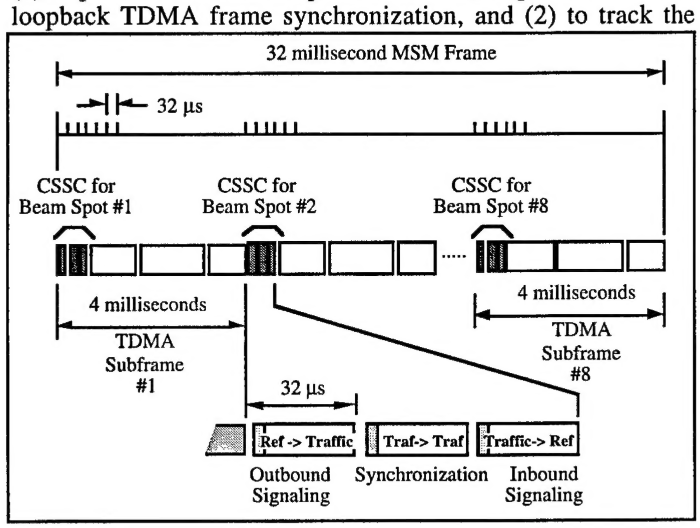

Fig. 6 - The CSSC system has a star topology and supports signaling and synchronization for earth stations distributed in up to eight antenna beam spots.

MSM slot transitions. The synchronization burst extends beyond the end of the MSM synchronization slot and is truncated when the downlink beam sweeps away from the earth station, during the transition from synchronization to inbound CSSC time slot

(Figure 8). This truncation causes the burst modem to lose carrier synchronization and then symbol clock synchronization. These truncation times are captured by the earth stations and averaged over time to reduce eventual uncertainties. Tracking of the MSM slot transition times is used for synchronization of the TDMA slots to the on-board MSM slots, and for long-term frequency-lock synchronization of a local 10 MHz oven-controlled VXCO (located in the Digital Terminal) to the MSM frame clock. The carrier ON/OFF transition times were simulated, showed to have relatively sharp delay distribution characteristics, and are used in the system for truncation time measurements.

C. System Timing and Performance Measurement

The burst modem front end in the TDMA Controller and Codec board (in the Digital Terminal) collects a number of timing and performance-related parameters for each 32-microsecond time slot. These parameter values are stored in Receive Burst Descriptors and includes information related to (1) UW detection (or not) with corresponding time offset, (2) satellite cell errors (number of valid Reed-Solomon codeword and number of channel bits in error), (3) received RF Power level (modem AGC signal level sampled at the center of the time slot), and (4) burst truncation timing (carrier ON/OFF transition at the end of the synchronization burst). The UW detection time provides round trip measurements, used for TDMA frame synchronization purposes. The burst truncation time is used for synchronization of the TDMA time slots to the MSM on-board the ACTS, and for long term synchronization the Reference Terminal and Traffic Terminals 10 MHz highly stable VCXO to the MSM clock.

Timing events are measured with a resolution of 34.5 nanoseconds, corresponding to one clock cycle at 29 MHz or 24 bits at 696 Mb/s. The RF power level measurements may be used for antenna pointing and for diagnostic purposes. The Network Control Processor in the Digital Terminal can also read information related to the operational status of the burst modem, and the up/down converter 30/20 GHz synthesizers lock to the Digital Terminal 10 MHz local oscillator.

IV. SONET Service Over Satellite

A. Internal Structure of the STS-1 Burst

The Gigabit Satellite Network architecture is oriented to supporting SONET-framed data and takes full advantage of the "SONET floating payload" principles to simplify synchronization of end-to-end communications and to reduce the buffers required to accommodate range and range-rate variations (Doppler shift) due to satellite movement.

Data is transmitted over the satellite Reed-Solomon encoded and arranged in blocks of 696-bytes called Satellite Cells (S-Cells). Figure 9 shows the structure of an STS-1 burst when transmitted using QPSK modulation. It uses ten 32-microsecond time slots (or forty 8-microsecond S-cell slots), with the first S-Cell time-slot being reserved for Guard Time and Burst Preamble.

Each S-Cell is composed of three parallel Reed-Solomon codewords with 232 bytes each. Each codeword is formed by 216 data bytes and 16 redundant check bytes, and is capable of correcting up to 8 byte errors per codeword. Almost all codeword data bytes (215 out of the 216 bytes available) carry end-user SONET payload data, with 1 byte per codeword (3 bytes per S-Cell) used as an S-Cell Postamble. Support of an STS-1 channel over satellite requires transmission of 32 SONET frames (25,152 bytes of payloads plus payload pointers) every 4 milliseconds. This data is transmitted scrambled, in 39 S-Cells (25,155 bytes = 39 x 3 x 215 bytes). Scrambling can be disabled on a per burst basis for testing purposes. Also detailed in Figure 9 are the relative positions and lengths of the Carrier Recovery Sequence (CRS), Symbol Clock Recovery Sequence (SCRS), and UW. The UW is a 37-bit long Barker sequence that, when inserted within the preamble bits used for clock recovery (sequence of 1's and 0's) show very low partial correlation peaks.

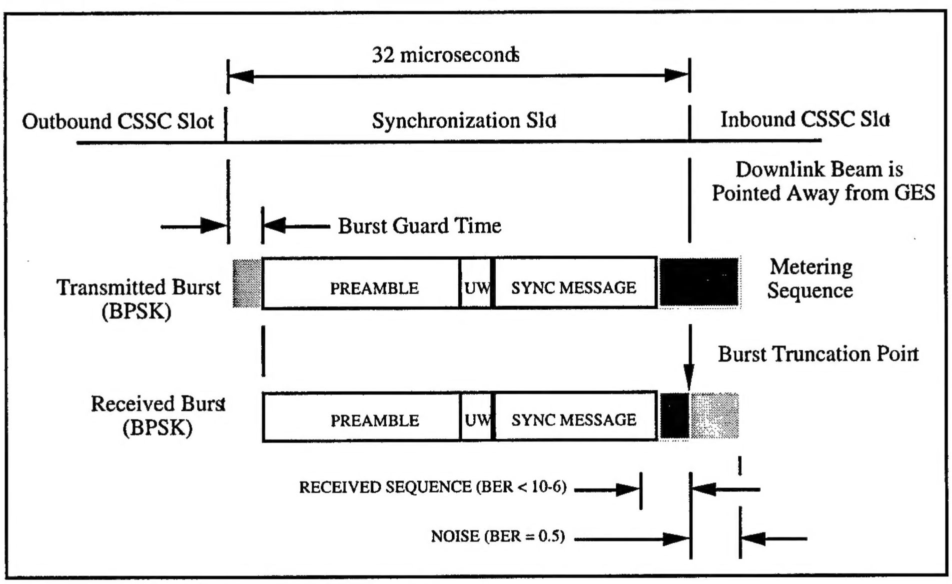

Fig. 8 - The truncation of the portion of the synchronization burst that extends beyond the MSM slot boundary allows the Gigabit Earth Stations to "capture" the MSM slot transition timing.

B. SONET Interface and Services

The Digital Terminal in the Gigabit Satellite Network performs the function of a standard Line Terminating Equipment (LTE) in the SONET hierarchy [7]. The Digital Terminal can be equipped with OC-3 and OC-12 interfaces, which are individually configured to handle concatenated or non-concatenated signals. In the uplink direction, the incoming STS-1 components of a non-concatenated STS-3 or STS-12 signal first have their payloads separated from their section and line overheads, and are then individually aligned (justified) to an internal 32-ms frame signal, which is phase locked to the satellite MSM frame. The STS-1 signals stripped from their section and line overheads (payload-plus-payload pointers only) are then routed independently over satellite to different earth stations. In the downlink direction, the outgoing OC-3 or OC-12 signal is built first by assembling the aggregate signal from received STS-1 payload plus payload pointer bytes originated in different earth stations, and then by multiplexing these payload signals with locally generated SONET section and line overhead bytes. Table 3 lists the SONET transport overhead signals [8] that will be supported in the deployed network.

Table 3
Support of Section and Line Overhead Functions in the SONET Interfaces of the Gigabit Satellite Network

<u>Section Overhead</u>	
Framing and STS-1 ID	yes
Section Error Monitoring (BIP-8)	yes
Section DCC, Section Orderwire, and User Channel	no
<u>Line Overhead</u>	
Pointer Bytes and Pointer Action Byte	
- Frequency justification	yes
- Alarm Indication Signal (AIS)	yes
Automatic Protection Switching (APS)	
- Line switchover	no
- Far End Receive Failure (FERF)	yes
Line DCC and Line Orderwire	no

C. Example of a SONET Network Over Satellite

The terrestrial interfaces in the Gigabit Earth Stations perform demultiplexing of SONET OC-3 and SONET OC-12 channels from the terrestrial lines into their respective STS-1 and STS-1/STS-3 components. Then these signals are flexibly grouped and routed over the ACTS Gigabit Satellite Network to implement a mesh network, as illustrated in Figure 10.

In the example, a point-to-point HPPI connection is performed through two OC-3 full-duplex channels over satellite established between GES #1 and GES #3. In this connection, GES #1 is provided with a single OC-12 interface while GES #3 has multiple OC-3 interfaces. In another instantiation, three ATM switches attached to GESs #1, #2, and #4 are connected over satellite using STS-1 and STS-3 channels. In the example, the STS-1 channels provided to the GESs through the OC-3 and the OC-12 interfaces are first demultiplexed in their STS-1 components and are then routed individually over satellite. The demultiplexing configuration performed by the Digital Terminals can be changed through operator commands to match almost any and user network configuration requirement.

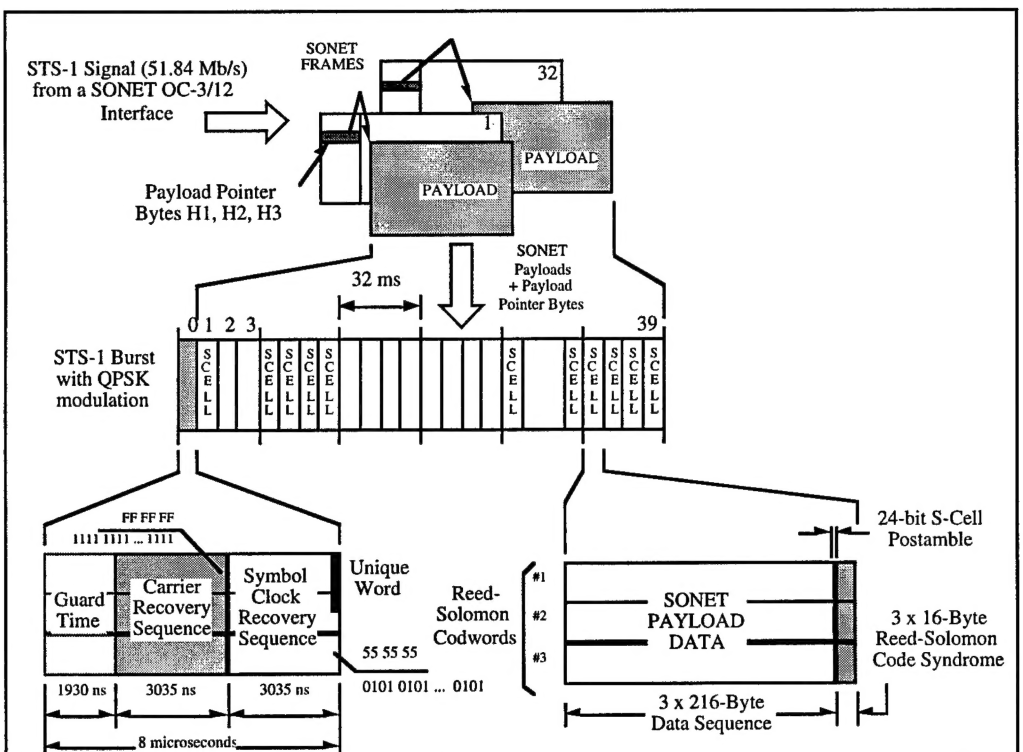

Fig. 9 - An STS-1 burst corresponds to ten 32-microsecond time-slots composed of 39 S-Cell time-slots of SONET payload data and one S-Cell time-slot for Guard Time and Burst Preamble.

V. Network Development Status

The ACTS satellite was launched on September 12, 1993 and, as of the date of submission of this paper, the spacecraft on-orbit checkout is practically complete, with the transition from on-orbit checkout to experimental operations planned to occur during December 1993. Initial integration of the burst modem, IR/RF, and antenna subsystems with the satellite has been performed, by Motorola (from Chandler, AZ), during the month of October, in parallel with the spacecraft on-orbit checkout tests. Since November the earth station has been undergoing extensive loopback testing aimed at achieving a detailed characterization of the non-linearities and filters of the ACTS transponders. The results of this testing and analysis may lead to adjustments in the burst modem and/or IF/RF equipment in order to achieve BER performance improvement. The integration of the earth station with the Digital Terminal and SS-TDMA subsystem is planned to begin in early 1994 at BBN, in Cambridge, MA. This integration will include the use of a digital satellite simulator being developed by BBN.

Integration and test of the TDMA subsystem and the SONET services over the satellite will be performed using three earth stations, two located at BBN and one at a West Scan or Fixed Beam site. Most of the initial network tests will be performed from the two earth stations at BBN. Testing of SONET OC-3 services over satellite through the East Scan Beam is scheduled to occur in the Summer of 1994. Integration of the earth stations located at BBN and at the selected third site will demonstrate provision of SONET service over satellite with on-board beam switching. Deployment of a five-node network fully controllable by an operator at the NMT and capable of supporting SONET OC-3 and OC-12 concatenated and non-concatenated services, in point-to-point and point-to-multipoint configurations, is scheduled to occur during the last quarter of 1994.

References

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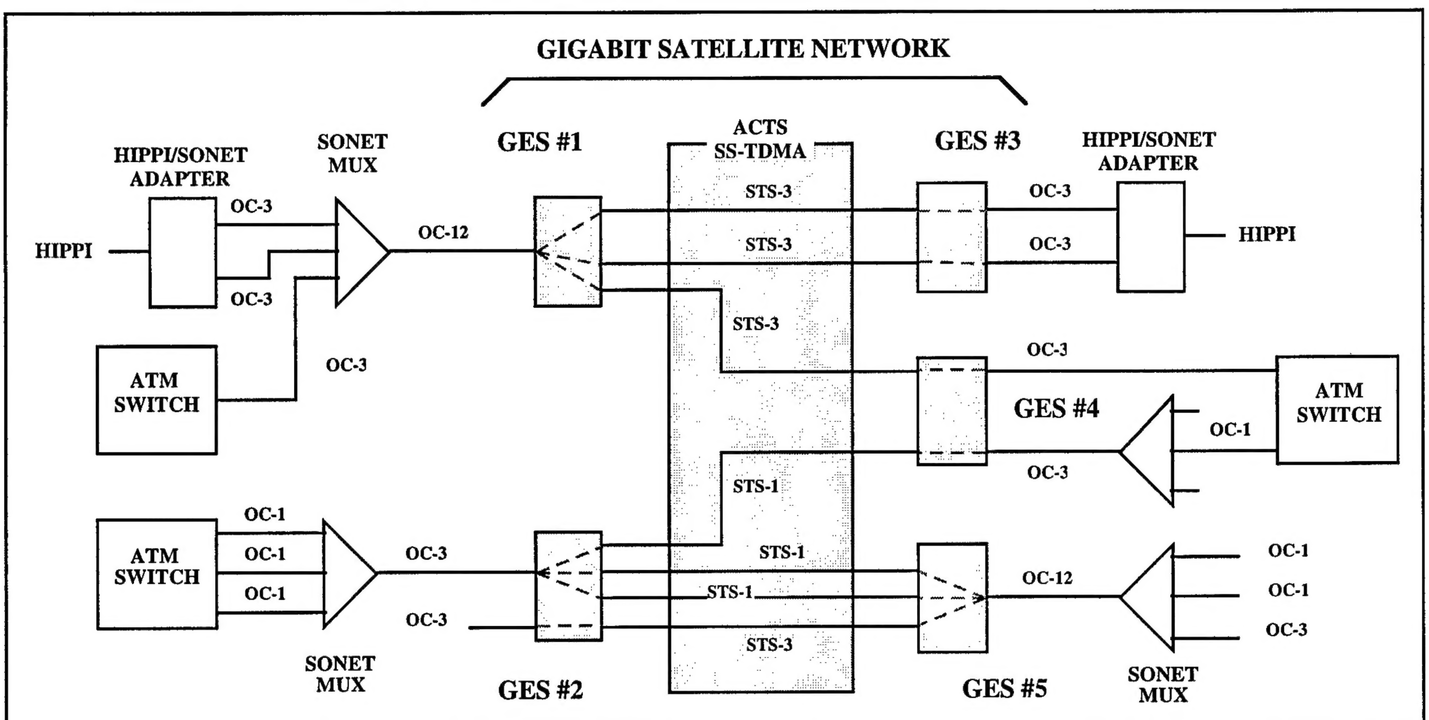

Fig. 10 - The Gigabit Satellite Network allows multiplexing and demultiplexing of SONET OC-3 and OC-12 signals into their STS-1 and STS-3/3c channel components and flexible routing of these channels over satellite.

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